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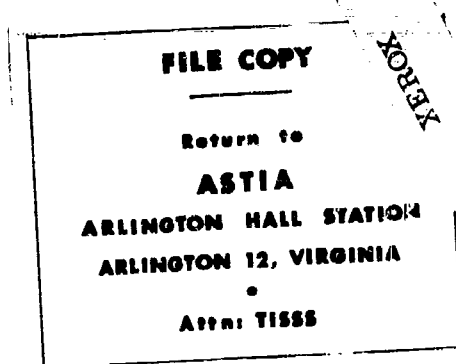
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A CONCEPT FOR RADIOLOGICAL (FALLOUT) DEFENSE IN NATO

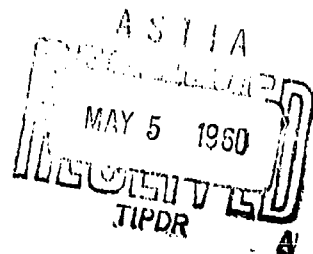
by

Harold O. Davidson

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A CONCEPT FOR RADIOLOGICAL (FALLOUT) DEFENSE IN NATO

The possession of atomic weapons by NATO forces initially gave us a position of strength in the face of much larger numbers of Soviet bloc land forces. Possession of this striking force may have been an important stabilizer for NATO in its infancy, for it provided the opportunity for development to a position of balanced strength. The "atomic problem" of this initial era was how to employ the available weapons for maximum effect against an aggressor. With the passage of time the increasing numbers of weapons available to NATO have lessened the significance of many early problems. But increasing numbers of weapons have also raised new problems. And most particularly, our irreversible entry into the era of two-sided atomic war capability has brought us to the problem of atomic defense.

The defense against enemy use of atomic weapons can be immediately divided into two aspects. One phase of the defensive problem is to minimize the number of weapons that an enemy could successfully deliver against intended targets. This involves the neutralization of bases from which he might launch weapon-carrying missiles or aircraft, and the air defense against weapons-

carriers in flight. One would certainly hope that this aspect of defense will be developed to a high degree of effectiveness. Nevertheless, the other aspect of defense must also be attended to. Adequate preparations are necessary to contend with the effects of those weapons that an enemy could succeed in delivering against NATO forces and their bases. This phase of defense can be further subdivided into two separate types of defense problems. The first is local damage control to minimize the consequences of blast, thermal, and initial radiation effects of an atomic detonation. The second problem is to minimize the consequences of the radioactive fallout hazard that would be created if an enemy employed surface detonations.

In designing a system of defense against radioactive fallout, there are two basic requirements to be met:

1. warning of the onset, or anticipated onset, of a radiation hazard, and
2. a means of reducing radiation dosages and/or their biological effects.

These two requirements react on one another. First, the maximum warning that may be achieved within purely physical limitations may render certain means of reducing dosage less feasible than

others. Secondly, for each of the defense measures that may be feasible within the maximum possible warning, there is likely to be a minimum warning time required for successful implementation. Thus, depending on the defense measures to be employed, it may not be necessary to aim for the maximum possible warning time in designing the warning system.

It is clear, therefore, that although warning is the first requirement for defense, one cannot intelligently develop the concept for a suitable warning system without some prior determination of the type of defense measure that the warning system is to activate. This does not mean that we must specify the defense measures in detail, but we should specify which of the various means for reducing radiation exposures (or their effects) will receive primary emphasis. The basis for this decision is available in existing knowledge, but the actual development of civil defense policy in the United States has been characterized by confusion and irrationality.

We will digress briefly to comment on development of civil defense policy in the United States, since this subject should be particularly interesting to a group considering the applications of operations research in national planning and policy determination. U. S. civil defense at the national level is the responsibility of a

Federal Civil Defense Administration that is entirely separate from the military establishments. Because of this separation the background of experience in military operations research on defense problems was at first neither readily accessible nor fully appreciated by civil defense planners.

In the first years after World War II our civil defense thinking continued along the line that had been developed in European wartime practice -- that of largely ignoring the discontinuity that had appeared in the character of strategic weapons. The unexpectedly early success of the Soviet Union in detonating an atomic weapon of its own precipitated a shift in U. S. civil defense policy for which there was inadequate planning.

"Mass evacuation" became the civil defense counterpart of "massive retaliation." There was no doubt a psychological connection, if not a logical one, for although "massive retaliation" had never been explicitly detailed by official sources, the popular notion of atomic war was the devastation of cities. The private advocates of strategic air power had drawn this picture very clearly. There was a 'common sense' appeal, therefore, in the notion of preparing to abandon cities (i. e., flee from danger). The feasibility of evacuation was presumed from the fact that successful "evacuations" of large numbers of people from U. S. cities occur at the end

of every workday.

As is so often the case with policies founded in crises, the simple logic of mass evacuation was defective. But once established, an enormous weight of criticism and detailed evidence was required to eliminate the mass evacuation concept. The detailed evidence was supplied largely through operations research, including studies sponsored by the Federal Civil Defense Administration.

In limited space we can mention, but not adequately summarize, the types of investigations made. The feasibility of evacuation was explored by detailed study of the mechanics of evacuating city populations as compared with daily population shifts within metropolitan areas. As might be expected, the removal of a city population was found to require much more time than the daily intra-city shifts.

Analyses of capabilities for forecasting fallout showed (as one would intuitively expect) that the probability density of fallout occurring at any given point was inversely related to its distance from the detonation. (It was assumed that yield, location, burst height, and meteorological data were known and the forecast made at time of detonation.) Thus the longer the time available to carry out evacuation before arrival of fallout (by virtue of distance from the

detonation), the poorer one's ability to discriminate between "safe" and "dangerous" areas.

The consequences of exposures that might be incurred before completion of evacuation to a "safe" place were examined. One of the significant features of fission products radioactivity is the relatively rapid build-up of dosage during the first hours of exposure, as shown in Fig. 1. This, of course, places a premium on taking the right defensive measures promptly. It may be noted that this figure shows "effective dose" rather than "total dose." The difference (which is negligible for fallout exposures beginning within 24 hours after detonation), is represented by "recovery" processes that elevate the lethal threshold for chronic as compared to momentary irradiation. This phenomenon was itself the subject of a special operations research study by the author,* for at one time the effect was thought large enough to be significant in fallout defense.¹

* We are not yet so far into the "scientific age" but that a great many people are still led to belief more readily through hope than through fact. Recently the U. S. popular press has acclaimed a "Cure for Radiation Sickness."² The "cure" has yet to be thoroughly tested on species other than laboratory mice, for which animals it approximately doubles the lethal threshold. Recovery from haematological injury is favorably affected, but there is no evidence of significantly large effects on the damage or recovery of epithelial tissues --or on the long term somatic and genetic injuries. At the present moment these developments hold much less promise for fallout defense than the reduction of dosage by absorption in shielding materials. (e.g., A factor of two increase in lethal threshold is to be compared with a factor of 10 or so in dose reduction offered by fox-holes, and factors of 1000 or more for simple earth-covered shelters.)

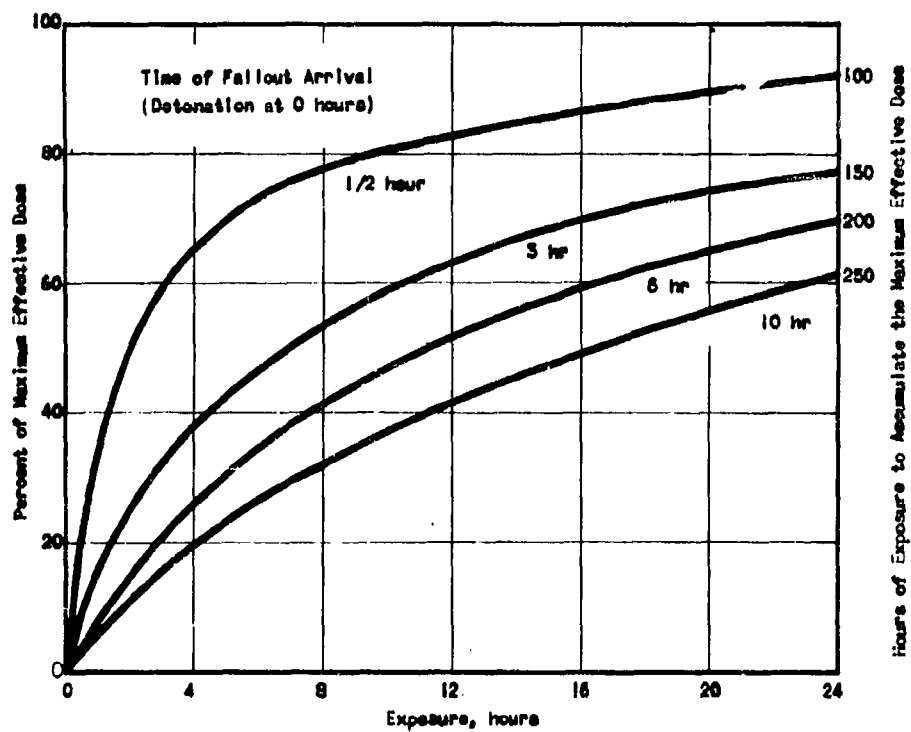


Fig. 1. Buildup of the effective dose during exposure to fission products fallout, for four different times of fallout arrival.

To weigh the significance of short exposures incurred in the process of evacuation against longer exposures at lower intensities that would be incurred by persons taking shelter in a fallout contaminated area, one may perform a "break-even" calculation as shown in Fig. 2. In this calculation we make several assumptions:

1. The dosage in shelter is integrated to infinity.
2. The fallout occurs instantaneously at any given point.
3. Persons in process of evacuation have a factor of two protection against gamma radiation (as compared with standing in the open) and essentially complete protection against betas.

From such calculations as these it is clear that the protection afforded by a shelter need not be exceptionally large in order for shelter to be preferred over relatively brief exposures incurred in efforts to escape an expected fallout hazard.

In lieu of further examples of U.S. operations research on the fallout defense problem, we should perhaps now inquire whether there are differences between the U.S. and European situations that would alter the conclusion -- namely, that shelter must be the primary means of defense. Evacuation rates, we suspect, would be lower in Europe than in the United States where the road network is based on (though not entirely adequate for) an automobile

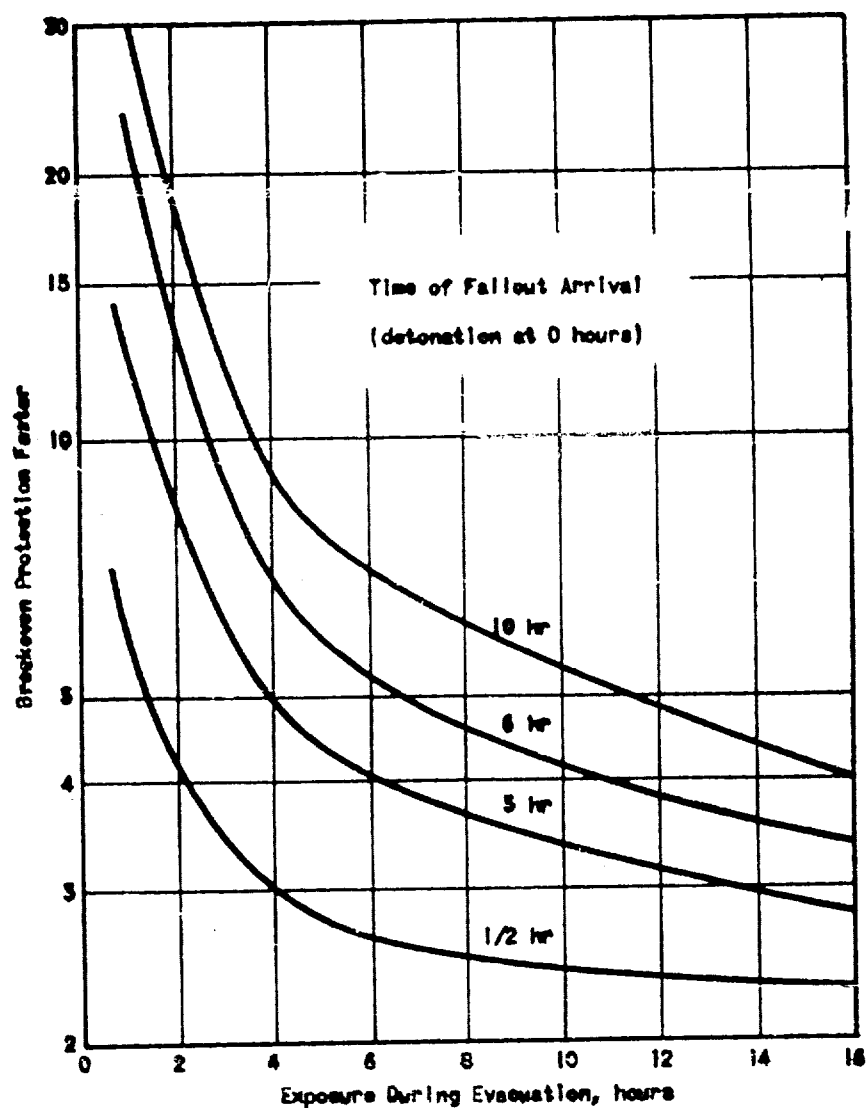


Fig. 2. Protection factor required for mortality incurred by remaining in contaminated area to be no greater than that incurred through brief exposures during evacuation with an assumed protection factor = 2.

density sufficient to evacuate the entire population. We note that evacuation on bicycles, mopeds, and the like would involve the additional hazard of beta exposures. These considerations tip the balance even further toward reliance on shelter in Europe.

Research on defense of the American continent has been primarily concerned with the threat of a strategic "megaton knockout punch." In Europe this problem perhaps has a lower relative likelihood than limited employment of kiloton weapons against tactical targets. (It is likely also that the considerations for minimizing the use of surface detonations would be greater for all parties concerned in Europe. This would reduce the occurrence frequency of the fallout defense problem, but would not change its character -- which we are now considering.) Although smaller yields would in general produce smaller areas of potentially lethal contamination, the time between detonation and arrival of fallout at the downwind extremity of the lethal area would also be shorter.* That is to say, maximum warning time would be shorter, and so this consideration also weights the argument in favor of shelter for fallout defense in NATO.

* For detailed data on fallout intensities, areas, and arrival times, see pp. 409 to 428 of "The Effects of Nuclear Weapons," U. S. Government Printing Office, Washington 25, D. C.

Let us turn then to the problem of a warning system to implement fallout defense. Who must be warned? We will say that maximum reliability of the warning system must be assured for those areas in which mortality would result if defensive action were not initiated and that a lower priority can be accepted for areas in which dosage would not exceed the lethal threshold even in the absence of defensive action. This distinction leads to the concept of a "potentially lethal" area of effect, which we define as the area within which the total dose received by a person remaining in the open from fallout arrival to infinity would equal or exceed 200 roentgens. These are all conservative conditions, so that the likelihood of mortality among persons outside the area so defined should be small.

The usefulness of the "potentially lethal area" concept begins to emerge when one examines some of its quantitative characteristics (as shown in the accompanying table), and in addition takes into account the fact that an atomic detonation automatically broadcasts visible and audible signals of its occurrence. Because weapon tests have generally been conducted under conditions favoring scientific observations, we do not have good experimental data on the ranges at which visual and auditory confirmation of an atomic detonation can be reliably made in different kinds of weather. The indications are,

however, that these ranges are on the same order as the downwind extent of the potentially lethal fallout area for surface bursts of weapons up to at least one or two hundred kilotons.

APPROXIMATE CHARACTERISTICS OF THE POTENTIALLY LETHAL AREA*

<u>Fission yield of weapon (kilotons)</u>	<u>Downwind extent of area (kms)</u>	<u>Time of fallout arrival at downwind limit** (hrs)</u>
20	35	1.2
200	100	3.3
1000	220	7.3

*Calculated on data and methods of source.³

**Assuming mean wind velocity of approximately 30 km/hr.

INDEPENDENT LOCAL DEFENSE CONCEPT

We are enabled by the preceding considerations to propose a simple warning system that will be adequate for persons in the "potentially lethal" area for detonations up to the yield (as yet undetermined) at which the downwind extent of the area begins to exceed the range of reliable visual and/or auditory detection. The concept (Fig. 3) is elementary in the extreme. The minimum requirement for the establishment of the system is a sufficient number of manually-operated radiation survey meters -- for example,

INDEPENDENT LOCAL DEFENSES

1. Maximum warning of a possible fallout hazard determined by range of detection of an atomic detonation by visual observation.
2. Minimum warning through detection of fallout onset by local monitoring.
3. "All Clear" determined by passage of the "period of risk" without detection of fallout.

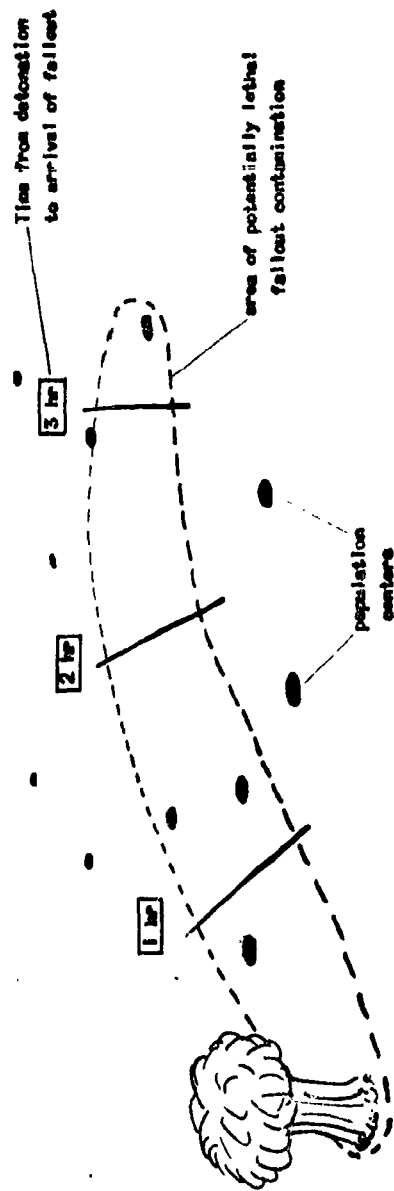


Fig. 3

the type used in uranium ore prospecting. It would be preferable that this instrumentation be augmented with automatic monitoring devices that would actuate alarms at relatively low threshold intensities, such instruments being of the sort that would be installed in an establishment using radioactive materials in significant quantities.

The proposed mode of operations involves three system states:

1. monitoring,
2. alert, and
3. implement defense.

Monitoring would be carried out at all times. Under non-alert conditions automatic devices would be preferred, but manually-operated survey meters could serve if the former were not provided. The arrival of fallout from an undetected detonation (i. e. , undetected by the local defense element) would trigger the alarm for an alert, whereupon all persons would prepare to take shelter. Survey meters would be employed to determine whether intensities were sufficiently high to require implement defense.

Within the range of visual and auditory detection of a detonation the alert state would be established immediately on occurrence of a detonation. Triggering of the monitor alarms by fallout arrival

would in this instance be the signal for implement defense. Manual survey meters would be used to determine a subsequent 'all clear.' "

We point out that this scheme offers persons within detection range a substantial advantage in the matter of warning. In fact, it utilizes the maximum possible warning time --which in the case of small yield weapons is none too much even at the downwind extremity of the potentially lethal area. On the other hand, persons outside the range of immediate detection are provided with no warning prior to fallout arrival. This is not desirable (and we shall later propose a modification of the concept), but the situation is not as serious as might at first be supposed.

In the case of small yields, absence of immediate detection will be associated with regions of lower initial intensities and potential accumulated dosages below the lethal threshold. Implementation of defense in minimum time is therefore not so critical as it is within the potentially lethal area. But what of the large yield detonations, for which we feel unable to affirm an immediate detection range equal to the extent of potentially lethal area?

We note first that absence of immediate detection would pertain in the more remote (from the detonation) parts of the potentially lethal area. We observe next, from our earlier table of character-

istics, that the time of arrival of fallout near the outer limit of this area increases with increasing yield. Finally, we recall from Fig. 2 that the rate of effective dose build-up declines with increase in the fallout arrival time. We find, therefore, that speed of response does not have the same high order of importance in these conditions as it does for those parts of the potentially lethal area in which intensities are higher and effective dose builds up more rapidly.

The absence of communications and operational organization above the local element should be noted. This lowers costs and avoids some of the reliability problems associated with more complex systems. A planning and training organization would be necessary to implement this concept, but it would be of minimal proportions. We also note that no special research and development effort is needed. A requirement for survey meter and monitor development exists in any case on account of the growing peaceful use of atomic energy.

The foregoing advantages are generalized in two propositions:

1. The concept will meet minimal defense requirements.
2. It will provide maximum effectiveness relative to its cost.

There are of course certain disadvantages associated with the

absence of information flow between elements. For example, all elements within immediate detection range would remain in alert status until passage of the "period of risk." Thus in actual use this system would "immobilize" more man-hours than would other systems that provide for information flow. Let us turn our attention therefore to a concept that in theory will permit maximum information distribution.

CENTRALIZED DEFENSE CONCEPT

In order to explore the full potentialities of a centralized fallout warning system we will not limit ourselves to "on the shelf" hardware, but will, where desirable, assume any type of equipment that seems within reach of our research and development capability. We will suggest characteristics of a fully automatic system, noting that most of its functions could be performed manually or semi-automatically, although the resulting degradation of system response time might severely limit its practical utility.

In Fig. 4 we show the defense system in phase 1 of the response to an atomic detonation. This phase would be completed in several minutes following a detonation. Meteorological data collected periodically and transmitted by automatic data links will have been

processed and stored in memory units of an electronic computer in the Fallout Defense Center (1 in Fig. 4). Field detectors (2) will be activated by a detonation and will automatically transmit data from which the computer estimates location, yield, and height-of-burst (3). In the case of an air burst, "all clear" signals will immediately be transmitted to local defense elements. In the case of surface bursts an "area at risk" will be calculated by programmed computer routine (4) and fallout risk warnings will then be transmitted to the proper local defense elements (5). Other local elements in proximity to the detonation will receive a "surface burst -- no hazard expected" advice message.

In phase 2 of the response two additional data sources come into play. Cloud-tracking radars and radiation monitoring stations will both provide inputs to the Center by automatic data links. The computer processes all information, produces an up-to-date situation display at the Fallout Defense Center, generates revised forecasts, and sends additional advice messages to local defense elements as required.

The advantages of this system (in the abstract, at least) are self-evident. We propose that the concept is within the NATO research and development capability to implement in from 6 to 10

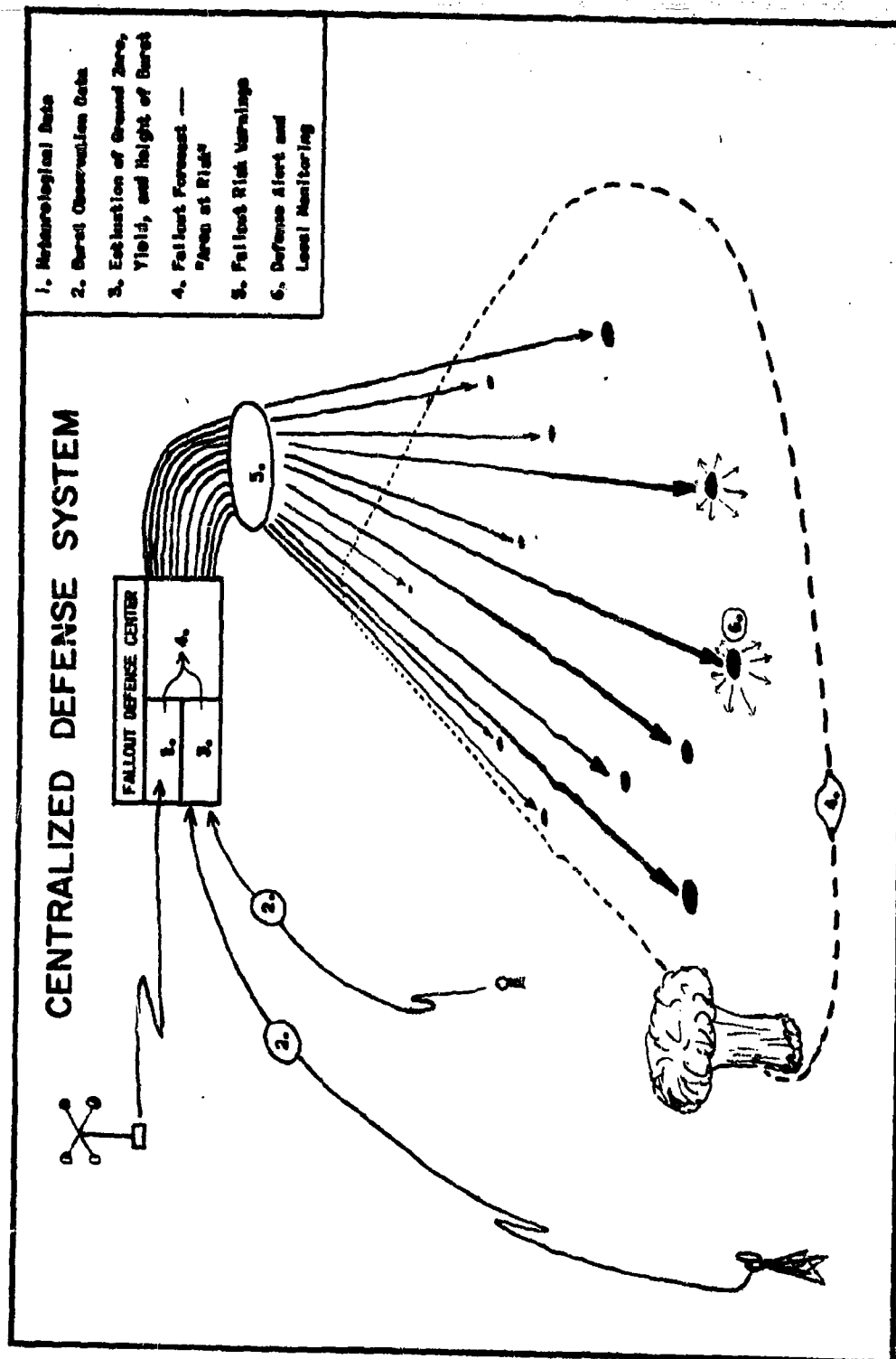


Fig. 4

years. Research and development resources are already in short supply, however. Further, the equipment procurement and installation costs for this system would be very high. We also predict a high annual cost to maintain the system. On pragmatic grounds, therefore, the solution proposed in this concept may be inappropriate for NATO.

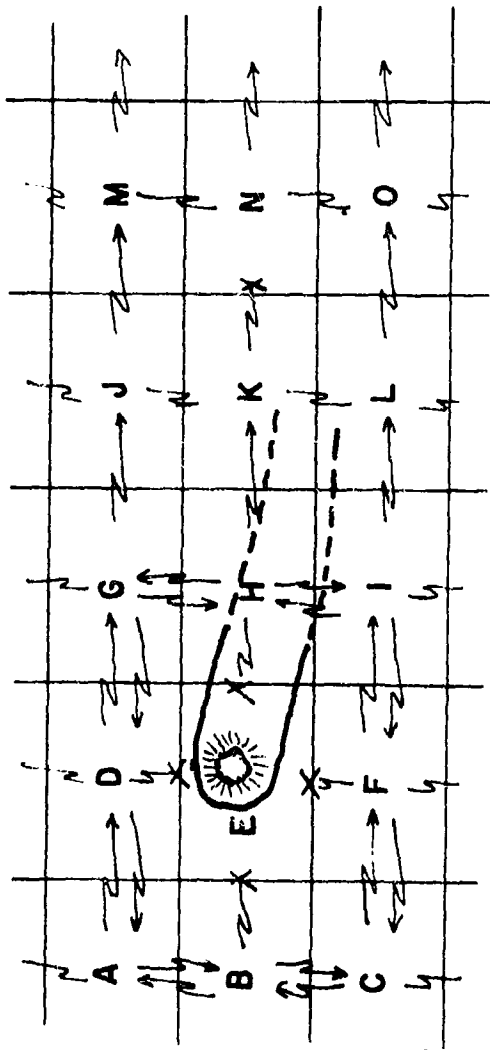
Is it possible to construct a less complex, manually-operated austerity version of the centralized defense system? To answer this question we note that the concept necessitates the collection, transmission, and processing of a large amount of information in a very short time with a very high system reliability, and the maintenance of this reliability over a long period during which the system is essentially in standby status. These requirements are largely incompatible with manual systems, and are certainly incompatible with a cheap manual system.

COUPLED CELL CONCEPT

In proposing the independent local defense we ignored resources for information exchange that exist in commercial telephone and police radio networks in civil areas, and the tactical communications networks that are available in an area of military operations. We

now propose to utilize this existing capability in order to increase the warning time for elements beyond the range of immediate detection and to reduce the immobilization of population resulting from unnecessary maintenance of alerts under the independent local defense concept. The most economical and readily available organization for this information exchange in civil areas, as we suggest, is the existing civil police system. Police officials are as a rule acquainted with their counterparts in neighboring communities and know how to contact them. We propose to utilize this circumstance in designing the "rules" for information flow. Specifically, we propose that each local defense element will have specified an average of, say, four neighboring elements with whom it exchanges information. The assignment of these correspondents, as suggested in the idealized diagram of Fig. 5, would be made in such a way that each element should receive the same information from three different sources. This redundancy serves two purposes. First, it provides at least a partial correction mechanism for erroneous messages that are certain to be generated in such a system under stress. Secondly, it provides some protection against the failure of communication links and human failures to implement the procedure. Note that the concept has "fail safe" characteristics in that if an

COUPLED CELL DEFENSE



1. On occurrence of an atomic detonation in cell E, adjacent cells A, B, C, D, F, H, and I go into full alert posture: a) full manning of control and monitoring stations; b) assembly of rescue teams; c) preparation by other persons to take shelter on signal.
2. Other defense cells within visual detection range of the detonation go into partial alert with full manning of control and radiation monitoring stations.
3. Loss of communication with E is verified and approximate location of detonation determined by the range of observational data by A-B, A-D, B-C, C-I, D-G, G-H, H-I.

4. Consolidated information is forwarded by coupled cells G-J, H-K, I-L; and cross-checked by J-K, K-L.
5. Onset of fallout is experienced first by H and communicated H-I, H-G, H-K; then relayed by pair coupling to A, B, C, D, F, J, L, K, H, and C. Additional information is relayed similarly.
6. Cells in expected path of fallout go into full alert. Cells A, B, C upwind of E return to partial alert and prepare to send rescue teams with radiation monitors into E.

Note: Communication failure at K-J will not incapacitate the system.

Fig. 5

element receives no information it operates in the independent mode, but upon acquiring information, is directed by the procedures to attempt communication. Thus, in addition to the "fail safe" characteristics, the specified procedures provide for automatic re-establishment of the couple-cell mode of operation wherever this becomes possible.

In reviewing the mode of operation of this concept, we note that the maximum warning time afforded by the detonation itself is still utilized within the range of detection by local elements of the defense. Thus the coupling of elements by lateral information flow accomplishes the following:

1. an earlier release of non-threatened areas from alert status,
2. an additional warning for threatened areas beyond the range of immediate detection of a detonation, and
3. a better basis for initiation of damage control and rescue operations in the immediate vicinity of the detonation.

No additional instrumentation is required for this concept as compared with independent local defense. As with the local defense concept, it avoids the need for special communications and for operating organization above the local element. It will, however, require a somewhat larger planning and training effort for successful implementation.

SUMMARY

The objective in this paper has been first to outline the fallout defense problem in broad terms. Several concepts for possible solution of the problem have been considered, ranging in nature from extreme simplicity to high technical elegance. Notwithstanding the current trends toward technical elaboration in military systems, industrial production, automobiles, and household appliances -- in fact, in nearly every aspect of our culture -- we propose that the best prospect for an adequate solution of the NATO fallout defense problem lies in the direction of simpler concepts. We suggest that a more detailed examination of these alternatives is a particularly appropriate subject for joint NATO operations research effort.

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